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FIELD OF INTEREST: 03.02.4

VOID FILLER FOAM ACCELERATED LOAD TESTING

Final Report

W.T. Burt

November 1976

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Prepared for

JOINT TECHNICAL COORDINATING GROUP
FOR
AIRCRAFT SURVIVABILITY

FOREWORD

The work reported herein was performed by Naval Weapons Center, China Lake, CA, under the direction of W.T. Burt, project engineer of the Survivability and Lethality Division. The accelerated load testing required for this program was conducted by Dayton T. Brown, Inc., under contract N00123-74-C-0639, with the direction of W.W. Schaaf, project engineer. The work was conducted between July 1973 and June 1974.

The work was sponsored by JTCG/AS and by the Naval Air Systems Command, AIR-03PAF, as part of the 3-year TEAS (Test and Evaluation, Aircraft Survivability) program. The TEAS program was funded by DDR&E/ODDT&E. The effort was conducted by the JTCG/AS Technology R&D Subgroup as Phase IV of the TEAS element 5.1.1.10, *Void Filler Foam*.

This report is the culmination of the first three phases of this program. Phases I, II, and III are summarized to provide the reader with an overview of the evaluation of this work. Phase IV was conducted to determine if the void filler foam installed around the main fuel tank of the A-4 aircraft could withstand the accelerated loads experienced during catapult launch and arrested landings. Phase V, the installation and testing in a flyable aircraft should be completed as soon as possible.

DISCLAIMER

Estimates in this report are not to be construed as an official position of any of the Services or of the Joint DARCOM/NMC/AFLC/AFSC Commanders.

NOTE

Information and data contained in this document are based on reports available at the time of preparation and the results may be subject to change.

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Naval Weapons Center

Void Filler Foam Accelerated Load Testing (U), by W.T. Burt. China Lake, CA, NWC, November 1976. 36 pp. (JTCG/AS-74-T-011, publication UNCLASSIFIED.)

This report presents the Phase IV program to qualify void filler foam for use in military aircraft. Phases I, II, and III of this task also are summarized in this report to show the evolution of the void filler foam concept.

The purpose of the foam installation around the aircraft fuel cell is to reduce projectile damage, fuel fire hazard, improve thermal protection and aircraft survivability. The accelerated load testing was conducted to determine the ability of void filler foam to withstand the loads encountered during aircraft carrier deck operations.

Results of the program show the void filler foam, used as a replacement for the backingboard on an A-4 aircraft, can withstand the loads associated with catapult launch and arrested landings.

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INTRODUCTION

This report is provided as a final report on Phase IV of the JTCG void filler foam work. The program objective of this phase was to determine if the void filler foam installed around the main fuel tank of the A-4 aircraft could withstand the accelerated loads experienced during catapult launch and arrested landings.

The results of Phases I[1], II[2], and III[3] are summarized in this report to provide the reader with an overview of the evaluation of this work. It is recommended that Phase V, the actual flight testing of this foam, be completed as soon as possible. All illustrations and tables are at the back of this report for further reference.

BACKGROUND

The purpose of the foam installation around the fuel cell in an aircraft is to:

1. Reduce fuel leakage and projectile hydraulic ram damage caused by projectile or fragment penetration of the fuselage skin and main fuel cell.

2. Reduce the fuel fire hazard of damaged aircraft both in flight and on carrier decks.

3. Provide improved thermal protection of the fuel tanks from external fires on carrier decks.

4. Improve the aircraft survivability by application of materials and techniques which are lightweight, economical, and compatible with quick retrofit operations.

Evaluation of combat data and fuel tank ballistic tests conducted at NWC (Naval Weapons Center), China Lake, CA, led to the conclusion that filling the void spaces surrounding the main fuel cell with fire and leak retardant foam would significantly improve aircraft survivability characteristics. The A-4 aircraft was selected as a typical aircraft structure to be used for evaluation of protective methods.

QUALIFICATIONS

The test results in this report are part of a series of tests which have led to selection of a void filler foam installed around aircraft fuel tanks which would provide the following:

1. Minimize fire initiation by denying oxygen.
2. Reduce fuel misting caused by impact of projectiles or fragments.
3. Minimize fuel leak paths into other standoff spaces within the aircraft.
4. Reduce the leak rate from the fuel cell wound by providing backing and sealing support superior to existing materials.

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[1] R.H. Fish (NASA-Ames) and D. Patterson (AVCO). *Technical Consideration in the Development of a Semirigid Void Space Ballistic Foam* (U). 1975.

[2] Naval Weapons Center. *A-4 Aircraft Survivability Technical Summary Report* (U), by John S. Fontenot, China Lake, CA, NWC. (NWC TP 5414, publication CONFIDENTIAL.)

[3] Naval Weapons Center. *Evaluation of A-4 Aircraft Fire Damage as a Result of Simulated Aircraft Carrier Deck Fire* (U), by W.T. Burt. China Lake, CA, NWC, February 1974. 118 pp. (NWC TM 2418, publication UNCLASSIFIED.)

5. Minimize damage caused by hydraulic ram effects by acting as an energy absorber.
6. Provide thermal protection to the main fuel cell from external fires on a carrier flight deck.

The development and testing of a foam which meets these requirements have progressed through a number of development cycles as described in the phases that follow.

Foam Development (Phase I)

Under a Navy program funded by AIR-03PAF, MCAIR (McDonnell Aircraft Company) was awarded a contract for fuel tank vulnerability reduction. As part of this program, MCAIR evaluated four types of foam material.

1. Scott LAS-103ZF (reticulated foam)
2. Goodyear DZ-70D461 (flexible foam)
3. NOPCO BX-249 (rigid TRI-AX closed cell polyurethane foam)
4. NASA 51 (semirigid polyurethane foam).

The materials were evaluated for resistance to ballistic impact and for physical properties, such as density and thermal stability. They also were checked for resistance to fuel, hydraulic fluid, water, flammability, and tendencies to corrode aluminum.

Ballistic impact tests were conducted on the samples resulting in the NOPCO (Northern Paper Company) BX-249 foam being the best choice. The main fuel cell would self-seal with no loss of fuel when supported by NOPCO foam after being impacted by .50-caliber API (armor-piercing-incendiary) ammunition. The other specimens reduced leakage but were not as effective.

Concurrently, NASA (National Aeronautics and Space Administration) and AVCO had been experimenting with fire retardant foams and were attempting to develop installation and production techniques for these foams. AVCO and NASA pursued a comprehensive test program on the NASA formulated foams. Three types of foams were evaluated separately and in combinations at various levels of reinforcement.

1. Polychloroprene latex flexible foam
2. Polyurethane semirigid foam (basic type 51 but with modification and glass reinforcement)
3. ICU (polyisocyanurate) semirigid foam
4. Combination mixtures of 2 and 3 above.

Since NASA developed these foams to be fire retardant, extensive thermal data were obtained on these mixes during development. Subsequent preliminary ballistic tests with .50-caliber API ammunition were conducted on many of the better configurations.

With the objectives of reducing fuel leakage and hydraulic ram damage, selected foam materials were ballistically tested in dry (no fuel) and wet (fuel) configurations. The foam materials were then evaluated for cracking, delamination, amount of coring caused by the projectile, size of foam particles generated by bullet penetration, and foam particle effects around bullet wounds. An additional rating factor of consideration was the amount of tank deformation that was induced by projectile hydraulic ram transmitted to the structure by the foam filler.

The majority of foams tested were successful in preventing fuel fire initiation due to projectile impact. Wet configurations were tested using JP-4 fuel, and dry configurations were also tested with fuel vapor. Based on the test results, a foam designated NASA 5ISA (Rigid Foam No. 2), was selected for further evaluation.

Foam Ballistic Testing (Phase II)

Ballistic tests were performed by NWC Aircraft Survivability Group on the A-4 in a baseline configuration using the recommended foams from NASA and MCAIR tests. In addition, NWC also tested a neoprene isocynate flexible foam, Flex-Foam, supplied by NASA.

NASA FLEX-FOAM. From test results, this foam was rejected as a candidate material since the leak rates after testing had not been reduced from the A-4 baseline configuration rates. In addition, the aircraft frames were twisted by excessive hydraulic ram action. A further drawback to the NASA Flex-Foam and all flexible foam material is that the standard baseline 36-pound backingboard must be retained to support the main fuel cell, thus adding a weight penalty to the aircraft.

NASA 5ISA AND NOPCO BX-249 FOAMS. These foams worked equally well under test conditions with little hydrolytic ram structural damage and no fuel fires. The NOPCO BX-249 supported the fuel cell slightly better than the NASA 5ISA, but tended to transfer hydraulic ram effects to the fuselage skin rather than absorbing them. Both system weights were high for the A-4 main fuel system (NASA 5ISA weighed 72.5 pounds and NOPCO BX-249 70 pounds), neither foam having been previously optimized for weight. Both foams were rejected as candidates because the triaxially-reinforced construction of the foams is difficult to manufacture; thus, the cost per unit system is high. This three-dimensional reinforcement may have application in future aircraft if production costs and installation problems can be reduced or where exceptional three-dimensional foam strength is required.

The rejection of these foams required NWC and NASA to continue the development of rigid foams striving for a reduction in system weight. NASA 5ISAB and 5B (two basic polyurethane foams) were modified in a total of six configurations (71 specimens). The fiberglass construction characteristics and densities of each combination are shown in Table 1. Two of these foam formulations (tests 4 and 6 in Table 1) were selected for further testing and evaluation. The mechanical properties and thermal performance of these two materials are shown in Table 2.

The data in Table 2 indicate that there is 1.5 minutes more thermal protection time using 5ISAB; although, later tests on 5B foam showed that 400 seconds protection to 400°F can be achieved by adding intumescent paint between the aluminum skin and the foam. A ballistic summary of test results showing the advantages of the NASA 5B over the 5ISAB foam is shown in Table 3.

Foam Test Conclusions

Any inert void space filler material will virtually eliminate the fire initiation hazard in the main fuel cell area. Flexible foams, though easily installed in the aircraft, do not adequately support fuel cells for self-sealing. Additionally, those tested did not appreciably reduce hydraulic ram damage to the aircraft structure.

Rigid foams, when faced with an anti-spalling material (ballistic nylon) will prevent fires, provide excellent fuel cell support (thus eliminating the need for backingboards), absorb hydraulic ram energy, and function as insulators for fuel cells in carrier deck fires. These rigid foams also can absorb blast and fragment energy from high explosive projectiles, thus significantly reducing damage to aircraft from this threat when detonated externally to the tank.

Full Scale Burn Test (Phase III)

It was a design goal that the modified aircraft could withstand a deck fire for at least 5 minutes before rupture of any major fuel tank. The 5 minutes have been deemed a sufficient time limit to activate necessary firefighting equipment and to extinguish the fire.

Previous ballistic impact testing of the A-4 had shown that the fuselage fuel tank area represents a significant fire hazard area, also that a ballistic impact in either fuel area could result in major structural damage and massive fuel leakage caused by the hydraulic ram effects. To reduce this problem, a quick-fix package was recommended for retrofit into the aircraft. This package, the Defended Aircraft Kit (also known as the Aircraft Modification Kit and the Passive Defense Kit), consists of the items listed in Table 4.

The primary objective of this test series was to determine the increase in cookoff time that the aircraft equipped with the Defended Aircraft Kit provides over a production aircraft. A secondary objective was the comparative evaluation of other coating and modifications techniques to establish which produced the best results.

It should be noted that the increase in aircraft weight due to this kit is 63 ± 1 pounds. Additionally, Kevlar-49 fabric should be considered as a lighter weight, stronger replacement for the ballistic nylon cloth.

During this test, two A-4 aircraft (one defended and one production aircraft) were burned in a simulated aircraft carrier deck fire. To simulate worst case conditions, both aircraft were topped with fuel, positioned on the NWC minideck, and under windless conditions, the deck was flooded with JP-5 fuel. The fuel was then ignited and allowed to burn until failure of the aircraft occurred.

Both aircraft had the engines and all potential explosive devices removed with the exception of the hydraulic and fuel systems. Varying levels of modification were then made to both aircraft to permit evaluation with the maximum number of protection techniques. Table 5 lists the final configuration of each aircraft.

The primary conclusions from this test series, as related to the foamed cell area, are that substantial improvement in aircraft fire survivability were achieved. The time-to-failure of the main fuel tank area was extended by a factor of 6.

ACCELERATED LOAD TESTING (PHASE IV)

Test Setup

SPECIMEN CONFIGURATION. NWC provided a stripped, trimmed-down, forward fuselage section of an A-4 aircraft consisting of the main fuel tank section. This section of the aircraft was shipped to Dayton T. Brown, Inc., Long Island, NY, where it was mounted and tested in a special test fixture. (See Figures 1 and 2.)

Upon completion of the mounting work, NWC personnel went to the Brown facility and installed the void filler foam around the main fuel cell in the Defended Aircraft Kit. Formulation by weight for this foam was:

A = Isocyanates, oz 116.5
B = Polyhydroxy compounds, oz 110.5
C = Glass, oz 40.0

The specific material specifications for this foam are in Tables 6 through 9.

Upon completion of the foam installation and reinstallment of the fuel tank, the section was mounted on a special cart designed to ride on the Navy-developed catapult test track located at the Brown facility. The section was then instrumented with accelerometers for slack load measurement. The fuselage section, containing the fuel cavity, was trimmed to the following maximum dimensions: length, 70 inches; width, 45 inches; and height, 65 inches. The actual accelerated load testing was started 16 April and completed 13 May 1974.

TEST FIXTURE. The test fixture was fabricated by Dayton T. Brown, Inc., to mount the fuselage section to the catapult. The fuselage section was mounted in the horizontal plane. The fixture supported the fuselage at four points: three points on Station 180 (two lower and one upper), and one point on Station 128 (nose wheel support). Figures 3 and 4 show the test setup with the fuselage mounted in the test fixture, and this in turn, is mounted on the catapult test track.

The catapult system used during this test consists of a Navy-developed catapult simulation which can reproduce the accelerated load conditions that an aircraft experiences during catapult launch and arrested landing.

TEST EQUIPMENT. All measurements were made using test equipment with performance certified and calibrated by the Dayton T. Brown Meteorology Department. The calibration system is set up to meet MIL-Q-9858A requirements, and the recommendations of the Standards Laboratory Information Manual by the Naval Standards Group, Pomona, CA. All instruments are calibrated at periodic intervals, with traceability to the NBS (National Bureau of Standards). A listing of the test equipment is included in Table 10 of this report.

A logbook was maintained on this project containing eight major categories: test schedule, job status, specification, time log, test equipment list, test data, administrative, and communications. All data, events, and communications pertinent to the job were kept current with the progress of the tests. Information included date, time, nature of test, test conditions, applied environment, and observations. The project engineer reviewed all test data on a daily basis and signified this review by his signature on each data sheet.

QUALITY CONTROL. The Quality Control System requirements were the same as test equipment but using the Department of Defense Handbook H-50. In line with the requirements set forth in these documents, this laboratory maintains a standards laboratory staffed with two engineers and seven technicians whose only function is calibration and maintenance of all electronic, mechanical, pneumatic, and hydraulic test equipment.

In addition, standard laboratory instruction and procedure manuals exist for each department to ensure optimum dissemination of testing instructions and test data.

Test Procedures

1. A pretest visual inspection of the test item was performed.

2. The fuselage section of the A-4 was mounted in the aircraft catapult simulator in the horizontal plane via a test fixture and instrumented with a response accelerometer. The test fixture supported the test item at four points.

3. The fuel cell was filled with 237 gallons (maximum tank capacity) of stained water, and subjected to 100 shocks simulating the catapult condition. Each shock consisted of a peak acceleration of 7.0 ± 0.5 *g* for 1.0 to 1.5 seconds. A visual inspection of the test item exterior was performed following each shock.

4. The fuel cell was then filled with 178 gallons (three-fourths full) of stained water, and subjected to 100 shocks simulating the arrested landing condition. Each load test consisted of a peak acceleration of 7.0 ± 0.5 *g* for 1.0 to 1.5 seconds. The test item was examined visually following each shock.

NOTE: Each shock pulse was recorded on graph paper and reduced to determine the actual shock pulse parameters.

5. NWC personnel then removed the fuel cell and inspected the foam backing.

6. A post test visual inspection of the test item was performed.

Test Results

The post test visual inspection of the test item revealed no anomalies. Testing was performed according to the above procedure.

A visual examination of the fuselage section after Shock 12 revealed a broken strongback. The strongback, which holds the top of the tank, was repaired and testing continued. Repairs are shown in Figures 5 and 6.

A tabulated summary of the catapult and arrested landing conditions can be seen in Tables 11 and 12.

Upon reducing the shock graphs, any pulse which had a high *g* reading was accepted as a valid pulse. A pulse which had a low *g* reading was considered invalid and was repeated. A repeated pulse can be seen at the end of the condition in which it appeared. The repeated pulse is denoted as the number of the shock pulse it is replacing followed by an "A" or "B".

A typical shock pulse can be seen in Figure 7. A post test visual inspection of the A-4 fuselage section performed at the completion of all testing revealed only minor scratches. No damage was noted to the foam backing other than minor indentations at points in the foam where voids were noted. Photographs of the foam backing were given to the cognizant NWC representative.

CONCLUSIONS AND RECOMMENDATIONS

The test results show the void filler foam used as a replacement for the backingboard on the A-4 aircraft can withstand the loads associated with catapult launch and arrested landings. The only problem areas found with the foam occurred in areas where lack of quality control during the installation process allowed for small internal voids. This problem can be overcome with more experience in the operation of the foam spray equipment. However, the slight indentation which occurred in areas where the mixture ratio was not optimum did not result in any tank wear or damage.

The cracks found in the structure on top of the tank noted after Shock 19 were a result of the weakening of the structure after it had been trimmed to fit the test fixture and the asymmetric loading caused by use of nonsymmetric load points. This cracking would not have occurred in a complete aircraft.

The additional rigidity added to the aircraft structure by the foam did not cause any structural deformation which might have occurred with changes in skin and structure loading patterns.

The successful completion of this test series reduces the flight qualification program to the final step (Phase V). This step, Evaluation in a Flight Status Aircraft, should be undertaken as soon as possible. This program will require installation of the foam in a flyable aircraft and evaluation during actual operation. It is estimated that this last step will require approximately 1 year to complete after initiation of the program.

Figure 1. Forward View of Fuselage Section in Fixture.

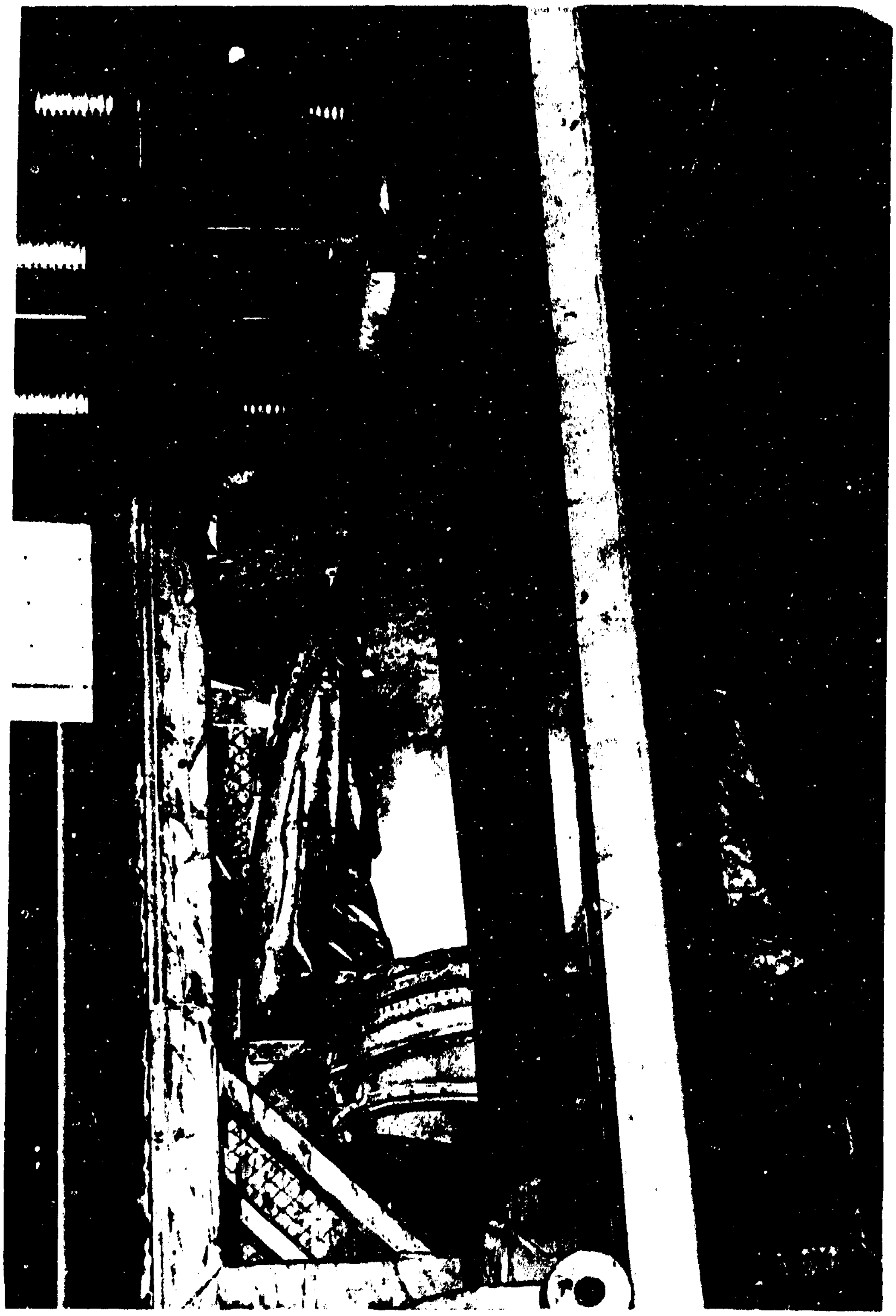

Figure 2. Side View of Fuselage Section in Fixture.

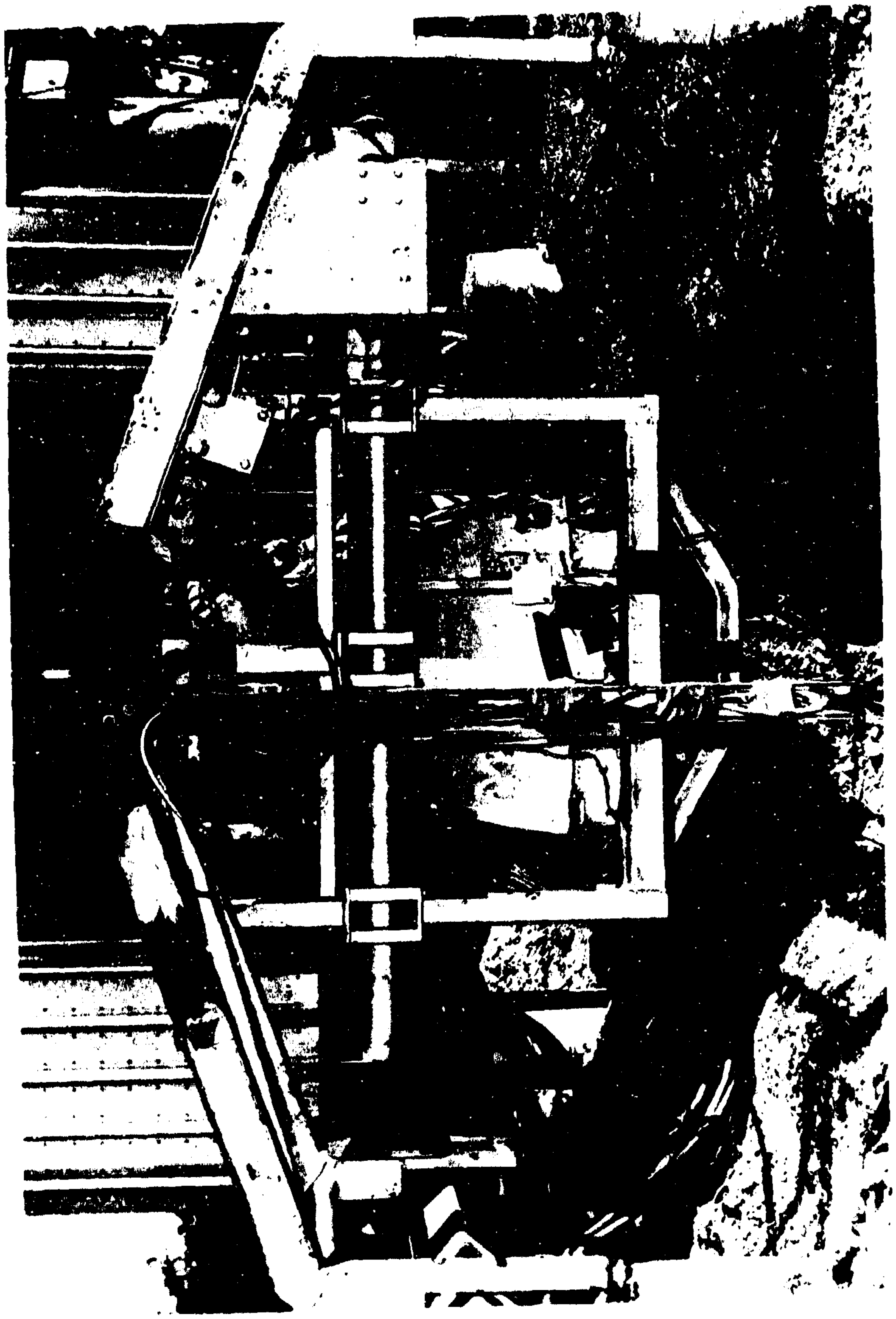

Figure 3. Forward View of the Test Setup.

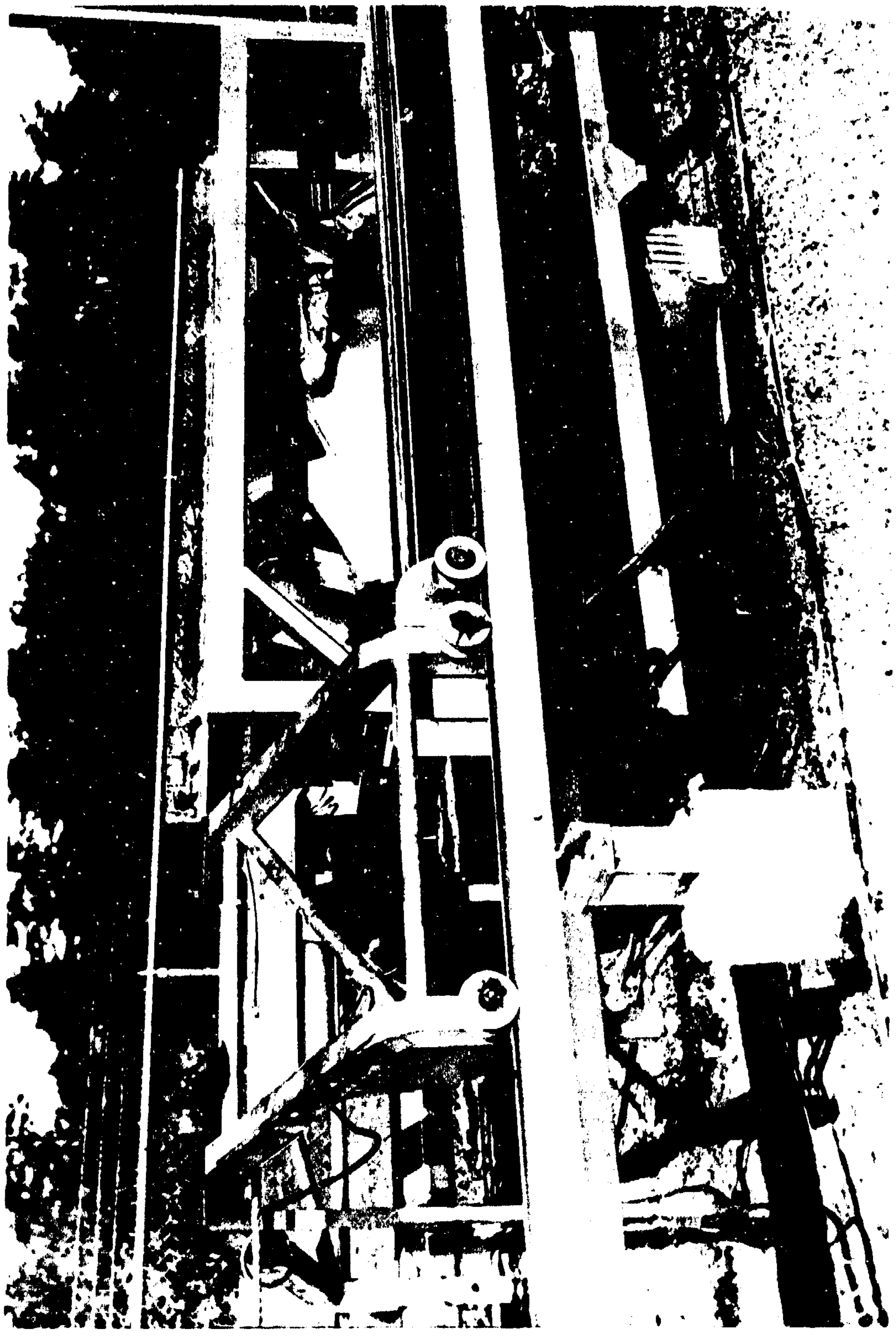

Figure 4. Side View of the Test Setup.

Figure 5. View of Repaired Area.

Figure 6. View of Repaired Area.

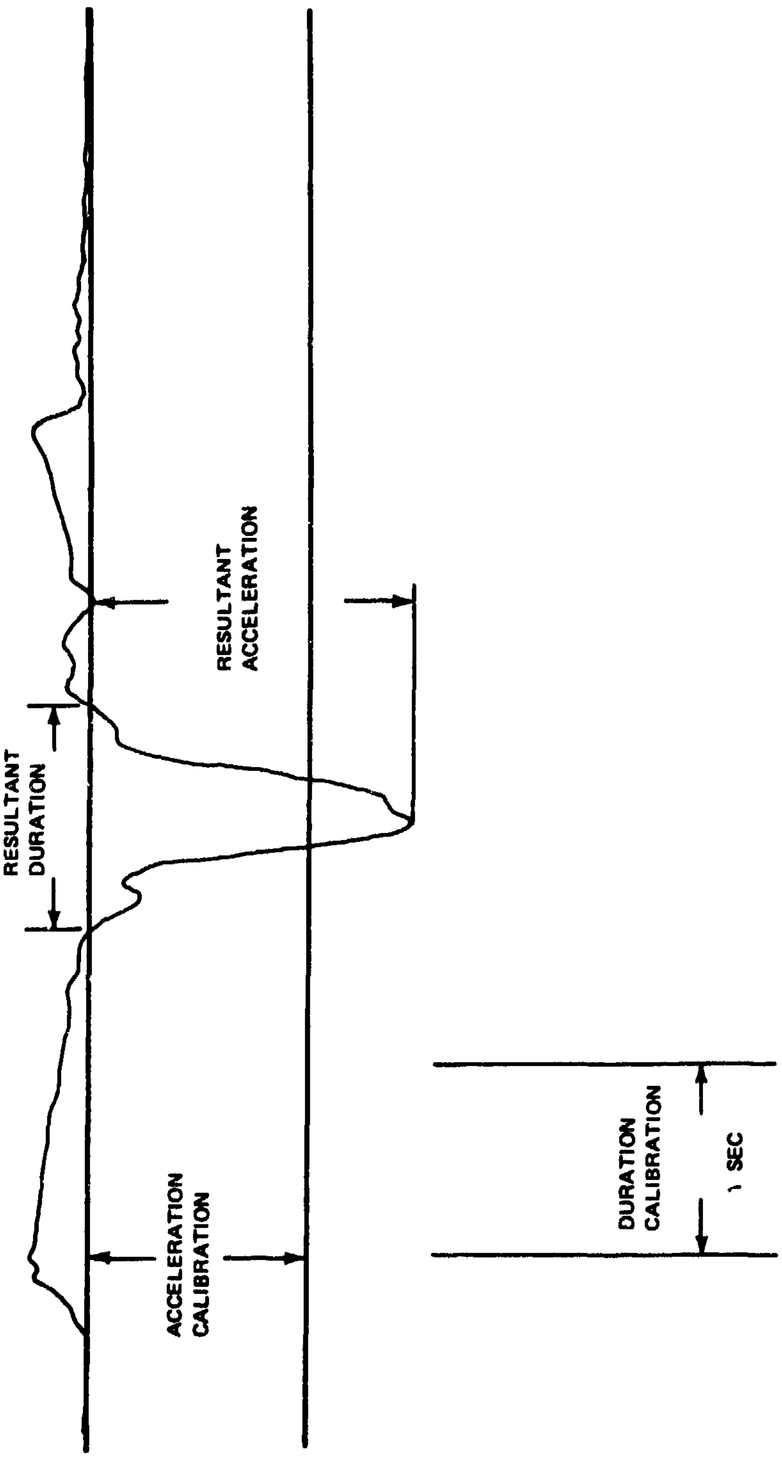

Figure 7. Typical Shock Pulse.

Table 1. NASA/AVCO Second Foam Screening of NASA 5ISAB and NASA 5B.

Test	Foam	Fiberglass characteristics	Density, pcf
1	5ISAB	Matting 3 layers	3.6
2	5ISAB	Matting 2 layers	2.5
3	5ISAB	Roving 60-strand chopped, loaded 15% by weight	2.5
4	5ISAB[a]	Roving 12-strand chopped, loaded 10% by weight	2.5
5	5ISAB	Roving 12-strand chopped, loaded 5% by weight	2.5
6	5B[b]	Roving 60-strand chopped, loaded 15% by weight	2.8

[a]Fibers were 2 1/4 inches long, all others in 5ISAB were 1 1/8 to 1 1/4 inches long.
[b]Fibers were 1 1/2 inches long.

Table 2. Mechanical/Thermal Characteristics of NASA 5ISAB and 5B Foams.

Property	5ISAB[a]	5B[b]
Compressive strength at 10% offset		
Stress perpendicular	16.4 psi	15.1 psi
Stress parallel	16.3 psi	21.0 psi
Elastic modulus		
Perpendicular	330.0 psi	280.0 psi
Parallel	260.0 psi	630.0 psi
Time to reach temperature at 2-inch depth in 3-inch block		
200°F	259.0 sec	181.0 sec
400°F	302.0 sec	208.0 sec

[a]Test 4 in Table 1.
[b]Test 6 in Table 1.

Table 3. Ballistic Test Characteristics of NASA 5B Foams Compared to the NASA 5ISAB Foams.

Panel results	
Entry	Exit
Less wound area damage	Similar direct wound characteristics
Substantially less permanent deformation	Greater foam matrix adherence to the substrate
Less susceptibility to fuel soaking	Less substrate deformation
Approximately equal low fuel leakage rates	Less fuel leakage
A 14% increase in composite foam density	A 21% increase in composite foam density

Table 4. The Defended Aircraft Kit.

Item	Description
1	A coating of intumescent paint placed over the entire inner surface of the forward fuselage section.
2	Ballistic nylon adhered to the inner area of the forward fuselage section covering three sides of the main fuel cell area and the bottom, but not the top or forward areas.
3	NASA-developed fire-resistant foam sprayed in the void spaces along three sides of the cell and between the bottom layers.
4	A second layer of ballistic nylon adhered to the foamed surface and then edged with Scotchclad rub strips.
5	A second coat of intumescent paint inside the cell area.
6	A new, improved main fuel tank capable of reliably self-sealing against the 12-mm API class of projectiles.
7	A thin corrosion-resistant, stainless steel skin bonded to the lower surface of the integral wing tank.
8	Rerouting of a fuel transfer line.
9	Deletion of the fuel cell backingboard.

Table 5. Aircraft Configuration.

Configured items	Unprotected aircraft	Protected aircraft
Wing materials	Aluminum 0.063 7075 T6	Aluminum 0.063 7075 T6 covered with stainless steel 0.018 17-7 PTL
Left wing	Intumescent paint	Intumescent paint
Right wing	Normal paint	Normal paint
Main tank	Production configuration	Defense kit
Cockpit	Production configuration	Ceramic blanket
Left gun bay	Intumescent paint	Intumescent paint
Right gun bay	Normal paint	Normal paint
Left wheel well	Intumescent paint	Intumescent paint
Right wheel well	Normal paint	Normal paint
Centerline bomb	Unprotected	Protected

Table 6. Material, 5A43 Foam.

Property	ASTM[a]/ apparatus	Unit	Value
Density			
real	D-1622	pcf	2.75
apparent		pcf	2.48
Porosity			
virgin foam	Kerr-Smith	%	1 to 3
actual	Pycnometer	%	9 to 10
Compressive strength, 10%			
perpendicular	D-1621	psi	28
parallel	D-1621	psi	29
Modulus,			
perpendicular	D-1621	psi	900
parallel	D-1621	psi	1000
Tensile strength,			
perpendicular	D-1623	psi	45
parallel	D-1623	psi	36
Shear strength		psi	24
Thermal conductivity	C-177	$\frac{\text{BTU-in}}{\text{ft}^2/\text{hr}/^\circ\text{F}}$	0.175
Limiting oxygen index	D-2863	%	19.75
Flammability	D-1692		Self-extinquishing
Maximum burn extent	D-1692	cm	3
Thermal efficiency Ames T-3 (JP-4 fuel fire, 2-inch thick, painted aluminum skin 0.040 inch)			
Time to temperature, 400°F		sec	400
Smoke $D_s = 132 \log\frac{(100)}{T}$ NBS - (MOD)			
Specific optical density Maximum		D_s	117 without flame; 201 with flame
at 2 minutes		D_s	103 without flame; 172 with flame

Table 6. Material, 5A43 Foam (Contd.).

Property	ASTM[a]/ apparatus	Unit	Value
Char yield, 600°C, N_2[b]	Thermal gravametric	%	30
Flame spread	2-foot tunnel		75
Friability, weight loss at 10 minutes, oak block		%	2
Specific heat, 150°C		cal/g	0.3
Thermal expansion, average to 250°F		in/in/°F	25 by 10^{-6}
Vibration (MIL-STD-510B) (23-pound weight on 6- by 6- by 6-inch foam block, 36 in^2)			
Resonant frequency,			
large search		Hz	70 to 75
second peak		Hz	100 to 110
Maximum to fracture, 11 seconds		g	17

NOTE: D_s stands for optical density, T stands for transmittance, NBS stands for National Bureau of Standards, and MOD stands for modified.

[a]American Society for Testing and Materials.

[b]Nitrogen environment.

Table 7. Environmental Solvents, 24-hour Immersion.

Solvent	Surface adsorption, %	Volume absorption, %	Volume change, %
Water	2.7	1.8	-1.8
JP-4	4.6	1.4	-2.6
JP-5	5.0	2.2	-0.7
Skydrol 500	6.6	0.8	-0.5
Ethylene glycol	5.8	0.8	-1.9
Standard hydraulic oil MIL-H-5606B (3)	7.0	1.1	+2.8

Table 8. Atmosphere Variation[a].

Temperature	Relative humidity, %	Time	Volume change, %
100°F	95	14 days	4 to 5
150°F	85	48 hours	Negligible
24-hour cycle, 85°F to 160°F	30 to 80	4 months	2 to 3
Salt spray, 120°F	100	10 days	4 to 5

[a]No noticeable change in compressive strength or other physical properties. (In contact with aluminum sheet, no corrosion observed.)

NOTE: This 51 type urethane system has been cycled to lunar atmospheric conditions on previous tests, also flown on Apollo 502 afterbody and return.

Table 9. Acoustical, MIL-STD-510B, in dB Attenuation.

Frequency, Hz	Density, 1.5 pcf[a]	51 foam
600 to 1200	11	20 to 22
1200 to 2400	28	14
2400 to 2800	42	30

[a]Boeing Specification BMS8-489 Class 3.

Table 10. Test Equipment for Catapult and Arrested Landing Tests.

Item	Manufacturer	Model	Serial number	Accuracy
Catapult	Dayton T. Brown, Inc.	001	001	Transfer instrument
X-Y recorder	Hewlett-Packard	7035B	132OAO7SS7	±1%
Accelerometer	Statham	±15 *g*	33-25	±5%
X axis drive	Dayton T. Brown, Inc.	10S	001	±1%

Table 11. Catapult Condition.

Shock	Calibration data		Test pulse		Remarks
	in/5 g	in/1000 msec	g	msec	
1	1.77	1.0	7.80	1060	High g
2	1.76		7.49	1100	
3	1.78		7.60	1040	High g
4	1.24		7.05	1040	
5	1.25		6.85	1100	
6	1.25		6.53	1060	
7	1.96		7.50	1150	
8	1.24		6.74	1050	
9	1.27		7.10	1000	
10	1.27		6.90	1040	
11	1.27		6.70	1000	
12	1.27		6.95	1040	
13	1.24		6.70	1020	
14	1.24		6.30	1000	Low g, shock repeated
15	1.24		6.20	1000	
16	1.21		5.90	1000	
17	1.22		6.20	1020	
18	1.20		6.30	1000	
19	1.20		6.30	1020	
20	1.19		6.30	2020	Low g, shock repeated
21[a]					Drag wire broke
22[a]					Drag wire broke
23	1.28		9.20	1030	High g
24	1.24		7.80	1030	
25	1.24		8.10	1030	
26	1.23		7.90	1100	
27	1.23		8.80	1020	High g
28	1.23		7.50	1010	
29	1.24		8.70	1100	High g
30[a]					Drag wire broke
31	1.21		7.40	1000	
32	1.21		7.40	1000	
33	1.20		7.50	1010	
34	1.20		7.40	1000	
35	1.20		7.40	1010	
36	1.20		7.45	1000	
37	1.20		7.45	1000	
38	1.20		7.50	1000	
39	1.20		7.30	1020	
40	1.20	1.0	7.40	1000	

Table 11. Catapult Condition (Contd.).

Shock	Calibration data		Test pulse		Remarks
	in/5 g	in/1000 msec	g	msec	
41	1.20	1.0	7.45	1010	
42	1.20		7.40	1030	
43[a]					Drag wire broke
44	1.20		7.30	1000	
45	1.20		7.30	1000	
46	1.20		7.30	1010	
47	1.20		7.30	1000	
48	1.20		7.20	1030	
49	1.20		7.30	1000	
50	1.20		7.20	1000	
51	1.20		7.30	1000	
52	1.20		7.20	1000	
53	1.20		7.20	1010	
54	1.19		7.15	1000	
55	1.19		7.20	1000	
56[a]					Drag wire broke
57	1.25		6.60	1090	
58	1.25		6.80	1100	
59	1.25		6.80	1100	
60	1.25		6.80	1100	
61	1.25		6.80	1110	
62	1.25		6.73	1070	
63	1.25		6.73	1070	
64	1.25		6.70	1100	
65	1.25		6.73	1100	
66	1.25		6.70	1070	
67	1.24		6.70	1070	
68	1.24		6.60	1100	
69	1.24		6.70	1080	
70	1.24		6.80	1080	
71	1.24		6.70	1090	
72	1.24		6.70	1090	
73	1.24		6.45	1080	Low *g*, shock repeated
74	1.24		6.45	1070	Low *g*, shock repeated
75	1.24		6.50	1080	
76	1.26		6.75	1020	
77	1.26		6.60	1000	
78	1.26		7.70	1030	High *g*
79	1.26		7.30	1010	
80	1.26	1.0	7.20	1030	

Table 11. Catapult Condition (Contd.).

Shock	Calibration data		Test pulse		Remarks
	in/5 g	in/1000 msec	g	msec	
81	1.25	1.0	7.00	1020	
82	1.23		7.40	1010	
83	1.23		7.30	1020	
84	1.23		7.35	1030	
85	1.23		7.30	1030	
86	1.23		7.30	1030	
87	1.23		7.30	1030	
88	1.23		7.30	1030	
89	1.23		7.20	1030	
90	1.23		7.30	1030	
91[a]					Drag wire broke
92	1.23		7.30	1020	
93	1.23		7.40	1030	
94[a]					Drag wire broke
95	1.22		7.10	1130	
96	1.22		7.10	1110	
97	1.22		7.20	1100	
98[a]					Drag wire broke
99	1.23		6.80	1100	
100	1.23		6.80	1100	
14A	1.21		6.60	1020	
15A	1.20		6.70	1030	
16A	1.22		6.50	1020	
17A	1.18		6.70	1020	
18A	1.20		6.30	1020	Low g, shock repeated
18B	1.23		7.50	1040	
19A	1.23		7.40	1030	
20A	1.21		7.40	1040	
21A	1.21		7.30	1030	
22A	1.20		7.10	1040	
73A	1.18		7.10	1020	
74A	1.19	1.0	6.80	1030	

[a]No record.

Table 12. Arrested Landing Condition.

Shock	Calibration data		Test pulse		Remarks
	in/5 g	in/1000 msec	g	msec	
101	1.26	1.0	8.20		Drag wire broke
102	1.23		8.10		Drag wire broke
103	1.22		7.80	950	High g
104	1.22		7.60	950	
105	1.22		7.60	950	
106	1.21		7.60	950	High g
107	1.21		7.40	950	
108	1.20		7.50	930	
109	1.25		7.40	950	
110	1.22		7.40	950	
111	1.22		7.20	950	
112	1.22		7.20	950	
113	1.22		7.20	950	
114	1.21		7.20	950	
115	1.21		7.20	950	
116	1.21		7.10	950	
117	1.24		7.50	950	
118	1.24		7.50		Drag wire broke
119	1.24		7.70	980	High g
120	1.23		7.75	980	
121	1.21		7.80	960	
122	1.21		7.80	920	High g
123[a]					Drag wire broke
124	1.20		7.30	1040	
125	1.21		7.20	1020	
126	1.20		7.40	1010	
127	1.22		6.90	1020	
128[a]					Drag wire broke
129	1.25		6.60	1050	
130	1.21		7.40	1040	
131	1.21		7.50	1050	
132	1.21		7.30	1030	
133	1.23		7.20	1040	
134	1.23		6.90	1010	
135	1.21		7.25	1030	
136	1.21		7.30	1040	
137	1.21		7.20	1030	
138[a]					Drag wire broke
139	1.20		7.10	1000	
140	1.21	1.0	7.15	1010	

Table 12. Arrested Landing Condition (Contd.).

Shock	Calibration data		Test pulse		Remarks
	in/5 g	in/1000 msec	g	msec	
141	1.21	1.0	7.15	1000	
142[a]					Drag wire broke
143[a]					Drag wire broke
144	1.14		7.50	1010	
145	1.16		7.20	1000	
146	1.21		6.80	1000	
147	1.20		6.70	1000	
148	1.19		6.70	1000	
149	1.17		6.65	970	
150	1.20		6.65	1000	
151	1.18		6.80	1010	
152	1.17		7.40	1000	
153	1.17		7.35	1010	
154	1.18		7.30	1010	
155	1.16		7.45	1010	
156	1.16		7.40	1000	
157	1.16		7.45	1020	
158	1.17		7.30	1020	
159	1.17		7.20	1000	
160	1.17		7.30	1030	
161	1.17		7.10	1000	
162	1.19		7.00		Drag wire broke
163	1.16		7.10	1000	
164	1.16		6.90	1000	
165	1.16		6.90	1000	
166	1.16		6.90	1000	
167	1.16		7.00	1000	
168	1.16		6.90	1000	
169	1.16		6.90	1000	
170	1.16		6.90	1000	
171	1.16		6.90	1040	
172	1.16		6.65	1010	
173	1.16		7.30	1010	
174	1.16		7.00	1010	
175	1.16		6.90	1020	
176	1.16		6.90	1000	
177	1.16		6.90	1000	
178	1.16		6.90	1000	
179	1.16		6.90	1010	
180	1.16	1.0	6.75	1010	

Table 12. Arrested Landing Condition (Contd.).

Shock	Calibration data		Test pulse		Remarks
	in/5 g	in/1000 msec	g	msec	
181	1.16	1.0	6.75	1000	
182	1.16		6.90	1000	
183	1.16		6.90	1010	
184	1.16		6.90	1010	
185	1.16		6.90	1000	
186	1.16		6.70	1000	
187	1.16		6.70	1000	
188	1.16		6.80	1010	
189	1.16		6.70	1000	
190	1.16		6.50	1000	
191	1.16		6.55	1000	
192	1.24		6.35	1000	Low g, shock repeated
193	1.16		6.91	1020	
194	1.15		7.00	1030	
195[a]					Drag wire broke
196	1.15		6.86	1040	
197	1.15		6.80	1030	
198	1.15		6.75	1020	
199	1.15		6.70	1020	
200	1.15		6.65	1000	
192A	1.15	1.0	6.75	1010	

[a]No record.

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This report presents the Phase IV program to qualify void filler foam for use in military aircraft. Phases I, II, and III of this task also are summarized in this report to show the evolution of the void filler foam concept.

The purpose of the foam installation around the aircraft fuel cell is to reduce projectile damage, fuel fire hazard, improve thermal protection and aircraft survivability. The accelerated load

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Void Filler Foam Accelerated Load Testing (U), by W.T. Burt. China Lake, CA, NWC, November 1976. 36 pp. (JTCG/AS-74-T-011, publication UNCLASSIFIED.)

This report presents the Phase IV program to qualify void filler foam for use in military aircraft. Phases I, II, and III of this task also are summarized in this report to show the evolution of the void filler foam concept.

The purpose of the foam installation around the aircraft fuel cell is to reduce projectile damage, fuel fire hazard, improve thermal protection and aircraft survivability. The accelerated load

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Results of the program show the void filler foam, used as a replacement for the backingboard on an A-4 aircraft, can withstand the loads associated with catapult launch and arrested landings.

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